Learning Unit – CSATs – miniature balloon investigations for high school students
Draft

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Introduction

This activity is a hands-on learning unit that permits students to explore some of the issues related to remote sensing using a simple instrument, CSAT, to measure temperature, pressure, humidity and light. Although the CSAT is not technically a remote-sensing instrument, it exposes students to some of the issues involved in remote-sensing including data acquisition, calibration and conversion into meaningful values, and data analysis. Students can also formulate hypothesis about expected measurements based on weather-related educational modules. Students can also compare and contrast the simple instrumentation to that of satellite and spacecraft-based instrumentation. Optional components include construction of a CSAT and imaging using a moored balloon if soldering expertise is available.

The CSAT or CricketSAT was originally developed by Bob Twiggs, Stanford University for freshmen engineering courses and is still used for that purpose. They also provide a useful introduction for mini-mission based investigations for high school students as project-based activities that can be implemented Earth Science, Physical Science or pre-engineering curriculum. Although CSATs are used as outreach tools, there is little material available to support teachers interested in engaging their students in these investigations. This learning module is a step-by-step teacher resource for this activity. It is based on a small remote temperature sensor and and incorporates data analysis and technology in scientific inquiry. It also supports elements of the following National Science Education Standards:

- -Science as Inquiry
- -Physical Science
- -Science and Technology

The version used in this activity is an enhanced CSAT circuit developed by Michael Fortney at the University of Vermont and tested with high school students in schools in Vermont and New York City by Austin and Fortney. This learning unit assumes pre-built CSATs, but optional instructions are available for teachers with soldering experience capable of guiding students. The circuits are fairly simple and easy to construct but require the availability of additional equipment – soldering stations, safety glasses, etc.

<u>Cost and requirements</u>
This activity requires an expenditure of about $400 in equipment and supplies, most of which is re-usable. Each activity described below provides a list of materials needed.

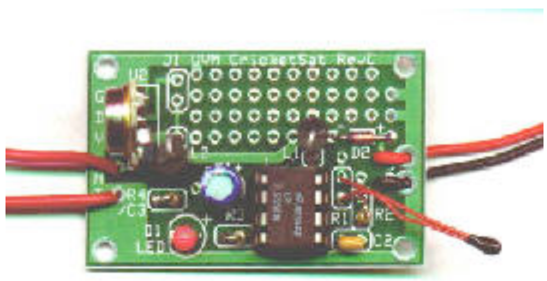
<u>Student clusters</u>

These activity modules can be integrated into existing Earth Science and/or Physical Science courses. Multiple CSATs should be obtained to facilitate student teams. Individual student coordination roles can be assigned within each team, e.g. calibration coordinator, launch coordinator, computer coordinator, etc. All activities can be undertaken in parallel with the exception of the actual launch since there is only one transmission frequency.

<u>Activities</u>

1. What is a CSAT and how does it work?
2. Testing the CSAT – listening to temperature changes
3. Using software to record measurements and calibration
4. Launching the CricketSAT
5. Analysis of results

1. **Description of the CSAT circuit measuring temperature**



<u>Background Concepts</u>

Physical Concepts – atoms, electrons, ionization

Electronics Concepts - Conductions, Insulators, Resistors, Current, EMF, Non-electrical energy, radio waves, volts, current flow, resistance

Electronic Components - resistors, capacitators, thermistor, timer circuit, radio transmitter

The CSAT circuit pictured above is a remote temperature sensor which converts temperature measurements from a thermistor into audio tones. The tones are broadcast over a radio frequency and measured using computer software. A calibration graph is developed to convert frequency to temperature.

<u>Basic CSAT components</u>

Resistors
Capacitators
Thermistor (for temperature version)
Timer circuit
LED
Radio transmitter
9V Battery
Antenna

2. **"Listening" to temperature**

Science concepts:

- Electromagnetic spectrum
- Sound waves
- Frequency and measurements of frequency

This activity allows students to hear the changes in tones emitted from the CSAT when temperatures change.

Materials:
CSAT
Wide-band receiver or inexpensive scanner
A bag of ice

Activities:
1. Listening to room temperature tones
Have students adjust the receiver to about 433MHz. If no tone is heard, try tuning just below or just above that frequency in small steps until a steady tone is heard. This tone represents room temperature.

2. Listening to colder tones
Place the CSAT in a bag of ice. Make sure that the electronics are protected from moisture and allow the antenna wires to protrude from the top of the bag. Leave the CSAT in the bag for a few minutes. Use the receiver to listen to the tone. Is there a difference in the tone? Is it higher or lower than the room temperature tone?

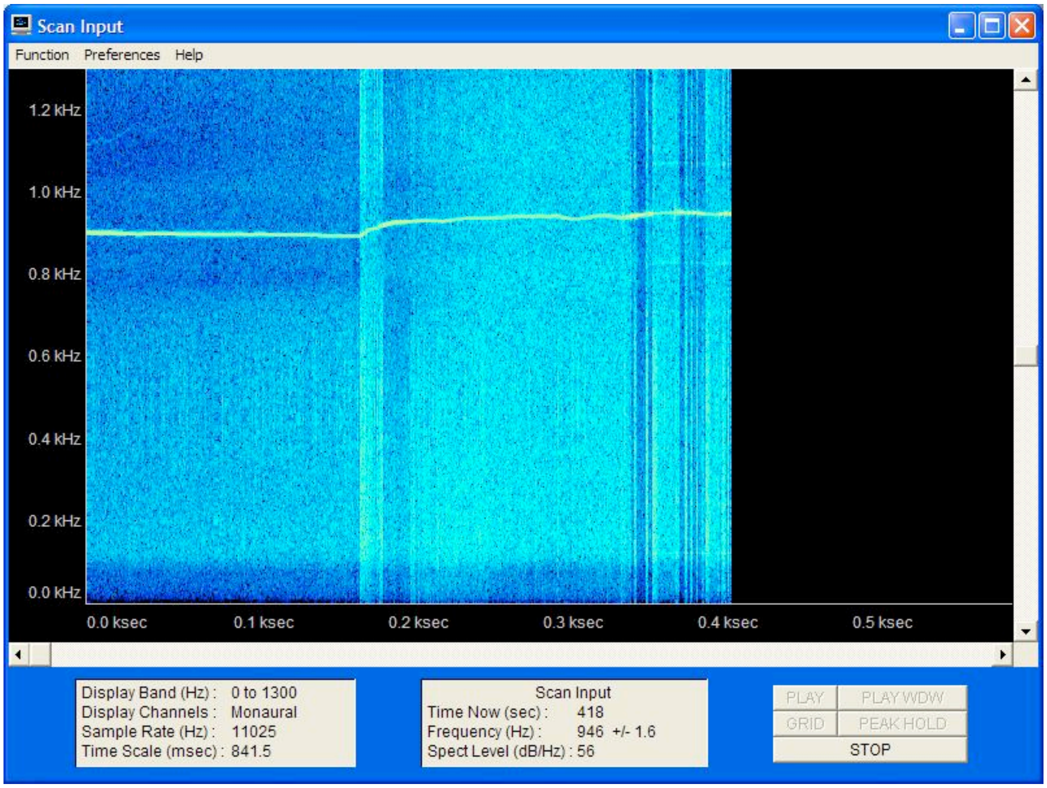
3. Listening to warmer tones
Place the CSAT in a warmer location – on or near a radiator or some other source of heat. Wait a few minutes for the thermistor to adjust. Use the receiver to listen to the tone. Compare the tone with the room temperature and cold tones? What are the differences? Is there a pattern?

3. **Calibrating and measuring temperature with the CSAT**

Materials needed:
PC with a sound card
Spectrogram software
Digital thermometer
An audio cable (found on computer speakers)
Wide-band receiver

a. The Spectrogram program can be downloaded from the Internet. The URL is: http://www.visualizationsoftware.com/gram.html. Spectrogram is free for a 10-day trial and costs $49.95 for permanent use. Spectrogram is audio spectrum analyzing software for Windows and can be used to relate the audio tones transmitted by the CSAT to temperature measurements. It has a self-extracting archive. Accept all defaults when installing and the program can be started from either the Start/All Programs menu.

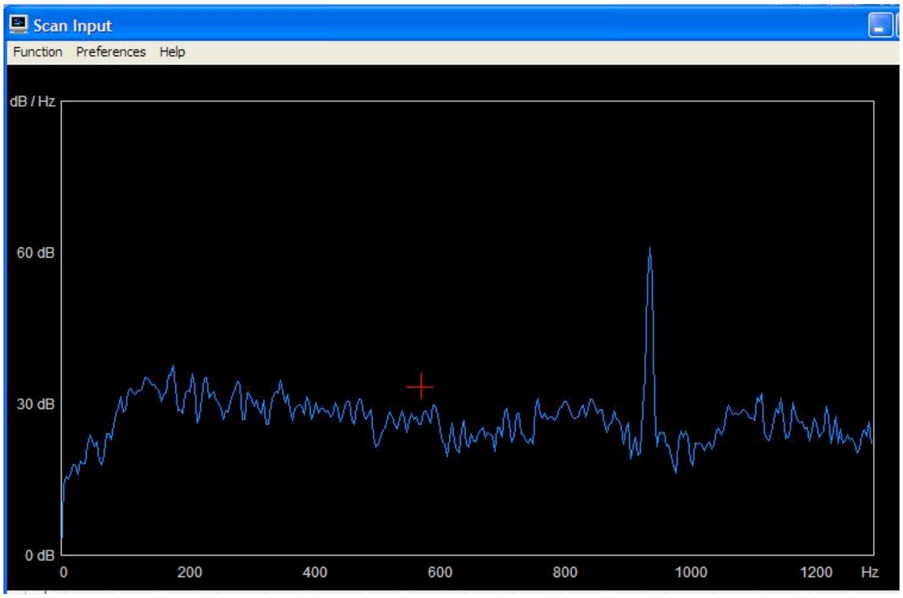
b. Connect one end of the audio cable to the input jack on the sound card. Connect the other to the speaker jack on the receiver. Switch the CSAT on and start Spectrogram. From the *Function* menu, select *Scan Input*. For the *Display option*, select *Scroll 1*. This option will scroll the frequencies recorded.



The strong horizontal band in the image above indicates the frequency recorded as a function of time. Move the CSAT around to different locations that are warmer or cooler and you should see the frequencies become higher or lower.

c. CSAT calibration
Now you will need to relate the frequencies to actual temperature measurements. The response is almost linear, however, it is best to take measurements at three points – room temperature, colder (bag of ice), warmer (radiator or other heat source).

Getting Started.
Select the STOP button on the lower right corner of Spectrogram. Now select Function/Scan Input and select Scope for the Display. Keep the CSAT in the room temperature location and measure the temperature with the digital thermometer. You should see something like the image below:



The fundamental frequency associated with the temperature measured on the digital thermometer is shown by the spike above at roughly 950 Hz. Move the mouse to the spike and in the status bar (not shown), you will see the exact frequency. This is the frequency for your room temperature measurement and should be recorded. Repeat this using your colder air and warmer air locations and each time record the fundamental frequency and corresponding temperature. This should be very close to linear.

Now ask students to predict the frequencies for intermediate temperatures. Review the equation for a straight line given two points.

4. **Launching the CSAT**
   Science Concepts
   -atmospheric soundings
   -balloon flight dynamics

The previous activity involved relating the audio frequencies of the CSAT to specific temperature measurements. Now the CSAT can be launched into the atmosphere to record temperature measurements aloft. This activity should be done in a park or playground away from tall buildings. The CSATs may not be recovered but you may attach a note indicating where you want it returned if found. The CSAT range is approximately 50 miles. This means that with a Yagi antenna connected to the radio, the audio signals can be heard 50 miles away with line-of-sight. This activity will involve inflating a small party balloon, attaching the CSAT and launching the balloon. Students will use the software and calibration graph to record the temperatures while the balloon is being tracked.

Materials:
Laptop
Wide-band receiver
Yagi antenna
Small party balloon
Party-size helium container

The small antenna on the radio receiver will not be able to pick up the audible signals over the range of the balloon flight. A 4-element Yagi antenna will work and these are available for about $50. You will need to borrow a laptop and install the Spectrogram software for the launch. Use the 10-day free trial unless you plan to continue to use the laptop for CSAT investigations.

Setup:
Connect the Yagi antenna to the radio. You may have to buy inexpensive connectors from Radio Shack, depending on the type of radio you have. Connect one end of the audio cable to the laptop (into the audio input jack – not the headphone jack) and connect the other end to the speaker jack on the radio. Select Function/File Input on the Spectrogram software and use the Scroll 1/Display option. Switch the CSAT on and verify that it is working properly. Inflate the balloon with helium and connect the CSAT to the balloon with string. Assign one group of students to monitor the laptop and determine the frequencies. Assign another group of students to write down the frequencies recorded. Another group can translate the frequencies to temperatures using the calibration graph.

5. **Analysis of results**
   Science concepts: atmospheric soundings

What should students expect in terms of the temperatures? Are they increasing or decreasing? How cold will it get? How high did the balloon go? What other inferences can be made with the data?

Students should compare the results with the observed soundings in their area. What differences are observed? Can they be accounted for by location, time of day, weather patterns, etc.? Can the comparison be used to determine the height of the balloon before burst?

6. **Related activities**
   Explore using other CSAT sensors – pressure, humidity, light, etc.